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A Cross-Country Test of the Natural Rate Hypothesis

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Abstract

This paper provides some evidence concerning the applicability of the Natural Rate Hypothesis (NRH) to the determination of Canadian real GNP. Lucas (1973) and Barro (1976) develop the proposition that anticipated money supply shocks will not affect real output or employment. Moreover, they show that unanticipated money supply shocks can affect real economic variables in that they cause agents to confuse absolute and relative price changes. Barro (1977, 1978) has tested the NRH by estimating a forecasting model of the money supply and using it to decompose observed money supply growth into its anticipated and unanticipated components. Forecasted money becomes anticipated money and the residuals become unanticipated money; these components are then used as explanatory variables in regression models of selected real economic variables. The money neutrality hypothesis is tested by applying classical testing procedures to the null hypothesis that the coefficients on current and lagged anticipated money supply growth are jointly equal to zero in these models. Barro was unable, on this basis, to reject the NRE for the U.S.

Disciplines

Behavioral Economics | Finance | International Business | International Economics

A Cross-Country Test of the
Natural Rate Hypothesis

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1. Introduction

This paper provides some evidence concerning the applicability of the Natural Rate Hypothesis (NRH) to the determination of Canadian real GNP. Lucas (1973) and Barro (1976) develop the proposition that anticipated money supply shocks will not affect real output or employment. Moreover, they show that unanticipated money supply shocks can affect real economic variables in that they cause agents to confuse absolute and relative price changes. Barro (1977, 1978) has tested the NRH by estimating a forecasting model of the money supply and using it to decompose observed money supply growth into its anticipated and unanticipated components. Forecasted money becomes anticipated money and the residuals become unanticipated money; these components are then used as explanatory variables in regression models of selected real economic variables. The money neutrality hypothesis is tested by applying classical testing procedures to the null hypothesis that the coefficients on current and lagged anticipated money supply growth are jointly equal to zero in these models. Barro was unable, on this basis, to reject the NRH for the U.S. His results generated a substantial number of related papers; for example, Liederman (1980) and Mishkin (1982), refined some of Barro's procedures and re-tested the NRH using United States data while Hoffman and Schlagenhauf (1982) and Attfield and Duck (1983) tested the NRH for countries other than the U.S.^{1/}

Our point of departure from this body of work involves a consideration of the international transmission of monetary disturbances. None of the papers cited above consider the effects of foreign money supply shocks on domestic output. This sort of omission might be reasonable for a "large" country (such as the U.S.) but would seem to be problematical when considering the issue of output determination for a "small" open economy (such as Canada). The central point of

the Monetary Approach to the Balance of Payments is that the world, as opposed to the domestic, money supply is the appropriate monetary measure under fixed exchange rates. The implication is that U.S. and Canadian money supply shocks should have similar effects on the Canadian economy in fixed rate periods. Moreover, a growing number of papers are suggesting that a flexible exchange rate does not insulate an economy from foreign monetary disturbances. For example, the Currency Substitution literature shows that asset holders may view domestic and foreign currencies as being highly substitutable within their portfolios.^{2/} If so, a foreign monetary shock would be expected to have qualitatively similar consequences to a domestic monetary shock even in the presence of a flexible exchange rate. Miles (1978, p. 174) summarizes this view by stating that:

"When the Federal Reserve increases the dollar money supply, the entire increase does not remain in the United States, with the price level in the United States adjusting to eliminate the excess supply of money balances; rather some dollars can be redistributed through private markets to France. With currency substitution in demand, therefore, the effects of the Federal Reserve's monetary policy are again not internalized within the United States. The increased supply of dollars is dispersed throughout the world, raising money supplies abroad. The increased money supplies imply that price levels abroad will rise as well."

A straightforward generalization of the NRH which follows the Monetary Approach to the Balance of Payments and the Currency Substitution literature is that domestic output should not be systematically related to anticipated changes in either the domestic or foreign money supplies but should be positively related to unanticipated changes in the supply of both domestic and foreign money.

The purpose of this paper is to determine whether U.S. and Canadian anticipated and unanticipated money supply shocks affect real Canadian GNP. Canada was chosen because of (i) the availability of quarterly real GNP data for Canada (ii) the ease of identifying a "large" and a "small" country, and, (iii) the fact that U.S. dollars are often used as a transactions medium in Canada. In the next section of the paper we explain how we derived our time series on anticipated and unanticipated Canadian and U.S. money supply growth. In section 3 we formulate and estimate a model of Canadian real GNP which can distinguish among the effects of the four types of money supply changes. Our conclusions are summarized in section 4.

2. Anticipated and Unanticipated Money Supply Growth

Our generalization of the NRH predicts that Canadian output responds systematically to only unanticipated movements in domestic and foreign (i.e., U.S.) money supplies. To test this hypothesis, it is necessary to decompose the observed money supply changes into their anticipated and unanticipated components.^{3/} One natural procedure is to model the money supply process. For example, one could try to estimate the reaction functions of the U.S. and Canadian monetary authorities and then obtain the predicted values of next period's money supplies. We viewed this approach as particularly imposing especially since we wanted to allow for cross-country feedback. Instead, consider the observed time series of Canadian and U.S. money supplies (seasonally unadjusted, quarterly M1 over the period 1948:I - 1981:IV) ^{4/} Let $m(t)$ and $m^*(t)$ denote the growth rates of the Canadian and U.S. money supplies respectively. We assumed that with their trends, means, and seasonal components removed, the observed realization of $m(t)$ and $m^*(t)$ could be viewed as a bivariate, covariance-stationary, indeterministic stochastic process with the following finite vector-autoregressive representation:

$$\begin{aligned} m(t) &= \sum_{i=1}^n \{a(i)m(t-i) + b(i)m^*(t-i)\} + v(t) \\ m^*(t) &= \sum_{i=1}^n \{c(i)m(t-i) + d(i)m^*(t-i)\} + v^*(t) \end{aligned} \quad (1)$$

In (1), the disturbances $v(t)$ and $v^*(t)$ are assumed to be random variables with zero means and constant finite variances. While both are assumed to be serially uncorrelated, they can be contemporaneously correlated with each other. Given these assumptions, the system has several desirable properties. First, equation set (1) allows for the possibility that each country's money supply can respond systematically (instantaneously and/or over time) to movements in the other country's money supply. Secondly, OLS estimates of the two equations will be consistent estimators which (by virtue of the same observable right-hand-side variables appearing in both equations) will be equivalent to Zellner's seemingly unrelated least squares estimation method. Finally, autoregressions have well-known properties as optimal, one-step-ahead predictors.^{5/} This is particularly appealing since the problem of deriving estimates of anticipated and unanticipated money supply changes amounts to generating one-step-ahead predictions of the two money supplies.^{6/}

In actually estimating the money supply model, (1), a constant, a trend, and three seasonal dummy variables were added to the right-hand-side of both equations. In addition, a dummy variable (equal to one prior to 1972 and equal to zero thereafter) was added to each equation to help capture the possibility of a structural shift in the money supply processes as a result of the move from a fixed to a flexible exchange-rate regime.^{7/} The lag length of the vector autoregression was determined by using a likelihood ratio test to compare the model's fit when four vs. eight lags were used and when eight vs. twelve lags were used. On this basis we chose a lag length of eight quarters.^{8/}

The eight-lag version of (1) was estimated by OLS, with the inclusion of the constant, trend, seasonal, and regime change variables which were described above.^{9/} In the case of the United States' money supply growth equation, the t-statistic on the coefficient corresponding to the regime-change dummy variable was -0.50 which (with 105 degrees of freedom) suggests that the change in the exchange rate regime did not change the time series character of U.S. money supply growth. On the other hand, in the Canadian money supply growth equation the regime-change variable's coefficient had a t-statistic equal to 2.07 suggesting that there was a significant difference in the time profile of Canadian money supply growth before and after 1972. The implication, is that the change in the exchange rate regime changed the money supply process.

The estimated residuals from these two equations were collected and became what we will refer to as unanticipated money supply growth. The predicted values are what we will call anticipated money supply growth. As we discussed earlier, the divergence between estimates of anticipated and unanticipated money supply changes and the corresponding values actually used by agents during the sample period is a potential source of bias in our ensuing tests.

3. Hypothesis Tests

The major hypotheses we chose to test were that i) anticipated changes in the U.S. money supply do not systematically affect Canadian output; ii) anticipated changes in the Canadian money supply do not systematically affect Canadian output; iii) unanticipated changes in the U.S. money supply do systematically affect Canadian output, and iv) unanticipated changes in the Canadian money supply do systematically affect Canadian output. We began with the following reduced-form model of the rate of growth of quarterly, Canadian real GNP, $y(t)$:

$$y(t) = K \times Z(t) + \sum_{i=0}^7 \{e(i)m^a(t-i) + f(i)m^u(t-i) + g(i)m^{*a}(t-i)\}$$

$$+ h(i)m^{*u}(t-i) \} + w(t) \quad (2)$$

In (2), $Z(t)$ is a 6×1 vector of exogenous variables which includes a constant, a trend, three seasonal dummies, and a dummy equal to 1 before 1972 and 0 afterwards (to capture any structural change in the response of Canadian GNP to money supply changes resulting from the change in the exchange-rate regime). The superscripts "a" and "u" on $m(t)$ and $m^*(t)$ designate the anticipated and unanticipated components of those two variables. The disturbance process $w(t)$ is assumed to have zero mean, to have a constant and finite variance, to be serially uncorrelated, and be contemporaneously uncorrelated with the disturbances in (1).

The choice of a lag-length of seven quarters was dictated to us partly by our model of the money supply process. Since, by construction, anticipated money supply growth (both Canadian and U.S.) is a weighted average of eight lagged values of Canadian and U.S. money supply growth rate, a lag length of more than seven quarters in (2) would have resulted in perfectly collinear regressors. This is one side of the identification problem which we referred to earlier which arises when the money supply is assumed to be determined by a pure autoregression in tests of money neutrality. It is our use of anticipated, rather than total, money supply growth in equation (2) along with the restriction of the lag length there that enables us to circumvent the problem. Our results (see Table 2) suggest that limiting the lag length in (2) to seven quarters is not very restrictive.^{10/}

Equation (2) can be consistently estimated by OLS under our maintained assumptions.^{11/} We will refer to that equation as the unrestricted model. We compared the fit of the unrestricted model to the fit obtained from estimated restricted versions of the model by using standard F-tests. The restrictions were of the form that various coefficients were jointly restricted to be zero. The results are summarized in Table 1.

The critical value of the F-statistic under the null hypothesis at the five-percent significance level is 1.77 when $T-k$ is 80 and q (the number of restrictions) is 16 and 2.05 when $q = 8$. At the one-percent level the corresponding critical values are 2.24 and 2.74 when q is 16 and 8, respectively. The restrictions that we are able to reject at the one-percent level are: i) Canadian and U.S. unanticipated money supply shocks do not jointly and systematically influence Canadian real GNP; ii) U.S. anticipated and unanticipated money supply shocks do not jointly and systematically affect Canadian real GNP; and iii) U.S. unanticipated money supply shocks do not systematically affect Canadian real GNP. The restrictions that we cannot reject at the five-percent significance level are i) Canadian and U.S. anticipated money supply shocks do not jointly and systematically affect Canadian real GNP; ii) Canadian anticipated and unanticipated money supply shocks do not jointly and systematically affect Canadian real GNP; iii) Canadian anticipated money supply shocks do not systematically affect Canadian real GNP; iv) Canadian unanticipated money supply shocks do not systematically affect Canadian real GNP; and, v) U.S. anticipated money supply shocks do not systematically affect Canadian real GNP.

In Table 2 we present a summary of the regression of Canadian real GNP on unanticipated money supply growth. Notice that the most significant coefficients are the coefficients on current and once-lagged unanticipated U.S. money supply growth both of which enter with a positive coefficient. The Durbin-Watson statistic is consistent with the assumption of serially independent disturbances in the model. To test whether the responses of Canadian real GNP to money supply changes differed before and after the change in the exchange rate regime we estimated the unrestricted version of the model over the two sub-sample periods pre-1972 and post-1972. Using a Chow test to compare the sum of squared residuals we were unable to reject the hypothesis of model homogeneity at the five-percent

significance level.^{12/} Thus, the change in the exchange regime affected Canada's money supply process but not the way in which U.S. and Canadian unanticipated monetary shocks affected output.

These results provide some support for our generalization of the Natural Rate Hypothesis. Anticipated money supply shocks, of any source, do not have systematic effects on real economic activity in Canada. Our most interesting result, perhaps, is that U.S., but not Canadian, unanticipated money supply shocks affect real Canadian GNP. This result is consistent with the view that Canada is a small country with its own money supply movements having a relatively small effect on the world money stock. Unanticipated increases in the large country's money supply (i.e., the U.S. money supply), however, have a relatively large effect on the world money stock and therefore act to increase Canadian output.

4. Conclusion

The aim of this paper is to generalize the money neutrality implications of the NRH, to account for the effects of external money supply shocks on domestic production. Given the widespread use of U.S. dollars in Canada, the Monetary Approach and the Currency Substitution literature imply that unanticipated money shocks should affect Canadian output regardless of the exchange rate regime. We specified and estimated a model of Canadian money supply growth, U.S. money supply growth, and Canadian real GNP in which we allowed for i) feedback between Canadian and U.S. money supply movements; and for ii) distinct effects among anticipated and unanticipated movements in each country's currency on Canadian real GNP. The results we obtained are consistent with a generalized version of the NRH: unanticipated foreign money supply shocks should be taken into account when considering the determinants of real economic activity. The results are also consistent with the observation that Canada is a small open economy. Canadian monetary shocks, of any sort, do not have significant effects

on Canadian real GNP; U.S. money supply shocks which are unanticipated do systematically affect Canadian output.

Footnotes

1/ Most of the papers testing the monetary implications of the NRH find 'mixed' support in that anticipated monetary shocks show a small amount of explanatory power.

2/ Some of the recent work on Currency Substitution includes papers by Boyer (1978), Girton and Roper (1976), McKinnon (1982), and Miles (1978).

3/ The extent to which our rest results are likely to be contaminated by errors in estimating the money supply has been discussed more generally in papers by Barro (1977), Abel and Mishkin (1981), Mishkin (1982), and, Hoffman, Low, and Schlagenhauf (1982).

4/ Our data were obtained from various issues of International Financial Statistics.

5/ See, for example, Koopmans (1974, Chapter 7).

6/ Abel and Mishkin (1981) and Sargent (1976) show that there is a potential identification problem in testing for neutrality on the basis of a reduced-form output equation when a pure autoregression is used to generate the money supply. We return to this issue below.

7/ There are several reasons to suppose that the money supply process will change as a result of a change in the exchange regime. Certainly central bank reaction functions may be altered as they no longer need to peg the exchange rate. Also, in a pure flexible rate period the monetary base cannot be altered by Official Settlements deficits or surpluses.

It is questionable as to the particular point in the 1971 to 1973 period that the greatest change in the international monetary system occurred. While we "break" our series at 1972, no qualitative differences arise if a different point in this sub-period is used.

8/ More specifically, in each of the two cases the two-equation model was estimated with the shorter and longer lag-length specifications. Under the null-hypothesis that the additional lags are superfluous, $T^* \{ \log |D_r| - \log |D_u| \}$ is asymptotically distributed as $X^2(q)$, where T is the number of observations, $\log |D_r|$ and $\log |D_u|$ are the logarithms of the determinants of the contemporaneous covariance matrices of the disturbances from the restricted and unrestricted systems, respectively, and q is the number of restrictions imposed. Following Sims' (1980) reasoning, we adjusted the statistic by replacing T with $T-k$ where k is the number of regressors in either of the two equations in the unrestricted system. Applying classical hypothesis testing methods, we were able to reject the four-lag system in favor of the eight-lag system but were unable to reject the hypothesis that the eight-lag system fits the data as well as the twelve-lag system.

9/ It is generally difficult to directly interpret the individual coefficients in autoregressions and so we have chosen to omit them from this report though they can be obtained from the authors upon request.

10/ The alternative used, for example, by Barro (1977) was to add an exogenous variable to the right-hand-side of what would otherwise have been a pure autoregressive representation of the money supply process. However, distinguishing between endogenous and exogenous variables generally involves a large degree of arbitrariness. Thus, Barro's choice of the U.S. budget deficit as being exogenous with respect to the U.S. money supply would be inappropriate if, for example, the budget deficit responds to interest rate movements which in turn reflect money supply movements.

11/ at a preliminary stage of our analysis, we added lagged values of Canadian and U.S. GNP to the right-hand-side of (2) and, using a X^2 test, were unable to reject the hypothesis that their coefficients were jointly equal to zero. Our failure to uncover feedback from Canadian GNP to the money supply process combined with results derived by Sims (1972) regarding the relationship between Granger-causality and econometric exogeneity, lends support to our maintained exogeneity restrictions.

12/ Since the number of observations in the second sub-sample (37) was equal to the number of free parameters in the unrestricted reduced-form for Canadian GNP (excluding the exchange-rate dummy which was omitted for this test), we chose to include only the current and first-lagged values of each type of money supply shock. The insignificance of other lagged values (see, e.g., Table 2) suggested to us that this was a reasonable procedure. The sum of squared residuals for the estimated model without allowing the coefficients to vary between the two sub-samples was .012543 and it was .011489 when the coefficients for each sub-sample were estimated separately. With 107 degrees of freedom in the restricted model and 94 degrees of freedom in the unrestricted model, the F-statistic, $F(13,94)$, was calculated to be 0.664.

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Table 1

Hypothesis Tests

Unrestricted Model:

$$y(t) = K \times Z(t) + \sum_{i=0}^7 \{e(i)m^a(t-i) + f(i)m^u(t-i) + g(i)m^{*a}(t-i) + h(i)m^{*u}(t-i)\} + u(t)$$

Residual Sum of Squares, Unrestricted Model (RSSU) = 0.008573, $\sigma^2 = 0.000105$

<u>Restrictions Imposed</u>	<u>Residual Sum of Squares (RSSR)</u>	<u>F-Statistic*</u>
f(i)=0, h(i)=0 i=0,...,7	0.014000	3.36
e(i)=0, g(i)=0 i=0,...,7	0.011600	1.81
e(i)=0, f(i)=0 i=0,...,7	0.010923	1.40
g(i)=0, h(i)=0 i=0,...,7	0.013317	2.82
e(i)=0 i=0,...,7	0.009460	1.06
f(i)=0 i=0,...,7	0.009307	0.87
g(i)=0 i=0,...,7	0.009983	1.68
h(i)=0 i=0,...,7	0.011064	2.97

$$*F = \frac{RSSR - USSR}{q \sigma^2} \sim F(q, T-k)$$

T-k = degrees of freedom unrestricted model = 82
q = number of restrictions

m^a = anticipated Canadian money supply growth, m^u = unanticipated Canadian money supply growth

m^{*a} = anticipated U.S. money supply growth, m^{*u} = unanticipated U.S. money supply growth

Table 2
Estimates of Coefficients on
Unanticipated Money Growth

$$y(t) = K \times Z(t) + \sum_{i=0}^7 \{f_i m^u(t-i) + h_i m^{*u}(t-i)\} + u(t)$$

i	f_i	h_i
0	3.309×10^{-4} (0.036)*	0.243 (0.081)
1	0.089 (0.037)	0.241 (0.080)
2	0.039 (0.038)	-0.017 (0.082)
3	0.038 (0.038)	0.085 (0.082)
4	0.022 (0.039)	0.022 (0.090)
5	0.066 (0.039)	0.145 (0.093)
6	-0.010 (0.039)	-0.077 (0.094)
7	-0.020 (0.040)	-0.036 (0.094)

F = 2.26
MSE = 1.18×10^{-4}

DW = 1.83
SSE = 0.0116

$R^2 = 0.326$
DFE = 98

*Standard Errors